A. G. Contract No.KR902917TRD
ECS File: JPA-90-149
Project: HPR-3(018)/R0018 02P
Section: Semi-Arid Precipitation Frequency Study

INTERGOVERNMENTAL AGREEMENT
BETWEEN
THE STATE OF ARIZONA
AND
THE YAVAPAI COUNTY FLOOD CONTROL DISTRICT

THIS AGREEMENT is entered into 3 September, 1990, pursuant to Arizona Revised Statutes, Sections 11-951 through 11-954, as amended, between the STATE OF ARIZONA, acting by and through its DEPARTMENT OF TRANSPORTATION (the "State") and the YAVAPAI COUNTY FLOOD CONTROL DISTRICT, acting by and through its Board of Directors (the "District").

I. RECITALS

1. The State is empowered by Arizona Revised Statutes Section 28-108 (A) (13) to enter into this agreement and has by resolution, a copy of which is attached hereto and made a part hereof, resolved to enter into this agreement and has delegated to the undersigned the authority to execute this agreement on behalf of the State.

2. The District is empowered by Arizona Revised Statutes Section 48-3603 to enter into this agreement and has by resolution, a copy of which is attached hereto and made a part hereof, resolved to enter into this agreement and has authorized the undersigned to execute this agreement on behalf of the District.

3. The State and the District desire to participate in a research study sponsored by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), entitled "Semi-Arid Precipitation Frequency Study". This study will provide the basic information to determine the characteristics of the Standard Storm. The Standard Storm will provide the County and the State basic flood design information for bridge, highway and culvert sizing. A detailed NOAA problem/research objective (revised 02/91) is attached. The study, hereinafter referred to as the Project, is estimated to cost $180,000.

THEREFORE, in consideration of the mutual agreements expressed herein, it is agreed as follows:

NO. 16004
FILED WITH SECRETARY OF STATE
Date Filed 9-3-91
Richard Mahoney
Secretary of State
By

II. SCOPE OF WORK

1. The State will:

a. Be the lead agency for the Project in the state. Participate by contract with the NOAA in the funding of the study, and with other Arizona political subdivisions in funding and accomplishing the Project.

b. Provide the District with copies of progress reports and such other related documents as available and appropriate.

c. Invoice the District for its portion of the Project costs in the amount of $10,000.00.

2. The District will:

a. Participate in the Project in the amount of $10,000.00.

b. Reimburse the State within thirty (30) days after receipt and approval of an invoice.

III. MISCELLANEOUS PROVISIONS

1. This agreement shall remain in force and effect until completion of said Project; provided, however, that this agreement may be cancelled at any time prior to the commencement of the Project, upon thirty (30) days written notice to the other party.

2. This agreement shall become effective upon filing with the Secretary of State.

3. This agreement may be cancelled in accordance with Arizona Revised Statutes Section 38-511.

4. The provisions of Arizona Revised Statutes Section 35-214 are applicable to this contract.

5. In the event of any controversy which may arise out of this agreement, the parties hereto agree to abide by required arbitration as is set forth for public works contracts in Arizona Revised Statutes Section 12-1518(B) and (C).

6. All notices or demands upon any party to this agreement shall be in writing and shall be delivered in person or sent by mail addressed as follows:

Arizona Department of Transportation
Joint Project Administration
205 South 17 Avenue, Room 118E
Phoenix, AZ 85007

Yavapai County Flood Control District
District Administrator
255 East Gurley Street
Prescott, AZ 86301

7. Attached hereto and incorporated herein is a copy of the written determination of each party's legal counsel that the parties are authorized under the laws of this state to enter into this agreement and that the agreement is in proper form.

IN WITNESS WHEREOF, the parties have executed this agreement the day and year first above written.

YAVAPAI COUNTY FLOOD CONTROL DISTRICT

By _____
BILL FELDMEIER
Chairman, Yavapai County Flood Control District Board of Directors

STATE OF ARIZONA
Department of Transportation

By _____
HARRY A. REES, Director
Transportation Planning Division

ATTEST:

By _____
ANN-LAWRIE AISA
Clerk of the Board

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26OCT

JPA 90-149

RESOLUTION

BE IT RESOLVED on this 26th day of October 1990, that I, JAMES S. CREEDON, as Acting Director of the Arizona Department of Transportation, have determined that it is in the best interests of the State of Arizona that the Department of Transportation, acting by and through the Transportation Planning Division, to enter into an agreement with the Yavapai County Flood Control District, for the purpose of defining responsibilities for the participation in a U.S. Department of Commerce, National Oceanic and Atmospheric Administration "Semi-Arid Precipitation Frequency Study".

Therefore, authorization is hereby granted to draft said agreements which, upon completion, shall be submitted for approval and execution by the Transportation Planning Division Director.

James S. Creedon

JAMES S. CREEDON,
Acting Director
Arizona Department of
Transportation

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as written

BOARD OF DIRECTORS
OF
YAVAPAI COUNTY FLOOD CONTROL DISTRICT

Minutes of Meeting

April 1, 1991

The Board of Supervisors resolved into the Board of Directors of the Yavapai County Flood Control District.

Present: Bill Feldmeier, Chairman; Carlton D. Camp, Vice Chairman; Cheral Brownlow, Member; Ann-Lawrie Aiea, Clerk.

Upon a motion by Director Camp, seconded by Director Brownlow, the Board voted unanimously to approve the minutes of the meeting of March 25, 1991, as written.

This being the time and date to open bids for photogrammetric services in the Chino Valley area, Chairman Feldmeier opened the following bids, each of which was for a flight height of 3,600 feet: Pictorial Sciences of Arizona, Phoenix, Alternate A $36,700, Alternate B $51,300; Cooper Aerial Survey, Tucson, Alternate A $37,494, Alternate B $37,294; Cooper Aerial of Phoenix, Inc. Alternate A $31,010, Alternate B $45,170. The Board voted unanimously, upon a motion by Director Camp, seconded by Director Brownlow, to refer those bids to the Flood Control District Administrator for study and recommendation. Flood Control District Administrator Elmer Claycomb told the Board that the estimated cost of this project was $57,198.

The Board considered a request for execution of Intergovernmental Agreement No. JPA90-149 with the Arizona Department of Transportation for a semi-arid precipitation frequency study. Mr. Claycomb explained that this agreement would commit the district to a contribution of $10,000 toward updating the Rainfall Frequency Atlas for Arizona, which is often used as the basis for calculating flood flows within the County. The Board voted unanimously to approve this agreement, upon a motion by Director Camp, seconded by Director Brownlow.

The Board considered a request for approval of an intergovernmental agreement with the Arizona Department of Water Resources, with Coconino County, and with the City of Sedona for maintenance and upkeep of the Sedona/Oak Creek Flood Alert System. Mr. Claycomb said that the agreement would require the district and Coconino County to contribute $5,000 each to be used for maintenance of the system. He said that each year the $10,000 maintenance fund would be replenished by each entity, depending upon how much had been spent. When asked by Director Camp if the City of Sedona would not be contributing as well, Mr. Claycomb responded that this was a way that funds flowed back to incorporated areas which have agreements with the district for flood control administration. Director Camp said he knew the City was very interested in this project. Mr. Claycomb said that the City was doing an excellent job with this project. He added that the information generated by this system would be especially useful to a warning for areas in the County downstream from Sedona. Director Camp asked whether the agreement points out procedures for the handling of these funds by the Department of Water Resources. Mr. Claycomb said he did not believe they were spelled out in the agreement. Deputy County Attorney Randy Schurr said he believed it would be possible to request that. Mr. [illegible] a provision in having this agreement executed and that [illegible]. No action was taken on this agreement.

JPA 90-149

APPROVAL OF THE YAVAPAI COUNTY ATTORNEY

I have reviewed the above referenced proposed intergovernmental agreement, between the DEPARTMENT OF TRANSPORTATION, HIGHWAYS DIVISION, and YAVAPAI COUNTY Flood Control District *and declare this agreement to be in proper form and within the powers and authority granted to the* ~~County~~ District *under the laws of the State of Arizona.*

DATED this 25th *day of* February, ~~1990.~~ 1991

Lee Randolph Glover

County Attorney

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Attorney General
1275 WEST WASHINGTON
Phoenix, Arizona 85007
Robert K. Corbin
XXXXXXXXXXXXX
Grant Woods

INTERGOVERNMENTAL AGREEMENT

DETERMINATION

A. G. Contract No. KR90-2917TRD , an agreement between public agencies, has been reviewed pursuant to A.R.S. § 11-952, as amended, by the undersigned Assistant Attorney General who has determined that it is in the proper form and is within the powers and authority granted to the State of Arizona.

No opinion is expressed as to the authority of the remaining parties, other than the State or its agencies, to enter into said agreement.

DATED this 28th day of August, 1991.

GRANT WOODS
Attorney General

James R. Redpath

JAMES R. REDPATH
Assistant Attorney General
Transportation Section

SEMI-ARID PRECIPITATION FREQUENCY STUDY

Unsolicited Proposal
for the States of
Arizona, Utah, Nevada and New Mexico

July 1990
(Revised February 1991)

WATER MANAGEMENT INFORMATION DIVISION
OFFICE OF HYDROLOGY
NATIONAL WEATHER SERVICE
SILVER SPRING, MARYLAND

SEMI-ARID PRECIPITATION FREQUENCY STUDY

I. PROBLEM STATEMENT

Current precipitation frequency data as represented in NOAA Atlas 2 (1973) for the 11 western states has been questioned in a number of areas. The National Weather Service (NWS) intends to review available data from all sources (Federal, State, local, and private), consider current statistical practice and techniques, and provide an updated report covering the semi-arid states of Arizona, Nevada, New Mexico, Utah, southeastern California, and western Texas. The product would be available as an atlas and in digitized format for ease in hydrologic applications.

NOAA Atlas 2 was based on available data through the mid- to late 1960's. The period of record for hourly data was relatively short. Only 73 recording raingages for all 11 western states had records of more than 30 years. Regression techniques developed for these studies required extensive manual calculation of data. Relations for durations less than 6 hours were not well founded and durations longer than 24 hours are not available. Depth-area and depth-duration relations were based on studies for other parts of the country. A lack of data did not allow for extensive studies of the relation between terrain and precipitation. These are all topics that will be addressed in the proposed NWS study.

The NWS has a long history of experience and expertise in precipitation-frequency analyses and in this study intends to add to this background by including studies of the fundamental distributions and fitting procedures used in the past as well as those currently available. It is important to consider state of the art techniques in a study that will receive nationwide attention and application. An adjunct to the study will be the involvement of an Independent Advisory Group to review all aspects of the proposed study. The advisory team will be drawn from the private and public sector and include hydrological, statistical, and water resources disciplines.

II. RESEARCH OBJECTIVE

The purpose of this study is to determine annual and seasonal precipitation frequencies from 5 minutes to 10 days for 2 to 100 years. The study results will be published as a NWS report and made available also as a digital file.

The research will review and process all available rainfall data for the homogeneous region of Arizona, Nevada, New Mexico, Utah, southeastern California, and western Texas and utilize accepted statistical methods It is recognized that the rainfall data as archived by the National Climatic Data Center (NCDC) may not be adequate to

accomplish the objectives of this research. Therefore, local, State, and Federal networks that are not compiled by the NCDC, will be added to the NCDC data to define frequency relations, local variations, as well as to provide details with regard to depth-area, depth-duration variations, seasonal and terrain relations.

New statistical techniques for the development of frequency distributions and objective spatial analysis developed over the past 30 years will be evaluated and used for the new frequency relations. The extensive adoption of automated procedures by hydrologists, engineers, and others requires that the results of these efforts be made available in a machine compatible format. Therefore, an additional effort will be directed at producing a digital file that is adaptable to most users.

III. BACKGROUND

The first national precipitation-frequency atlas for durations up to 24 hours for the contiguous United States was prepared by Yarnell in 1935. Subsequently, this work was updated by the National Weather Service beginning in the 1950's. Currently, the NWS has ten reports which provide the standards for precipitation-frequency relations for the 50 states, Puerto Rico, and the Virgin Islands for durations from 5 minutes to 10 days. For some of these reports additional data has been collected for another 30 years.

The NWS recognized the need to review these publications. About two years ago the NWS began a pilot study of the precipitation-frequency relations in Pennsylvania and West Virginia with funding from the Soil Conservation Service. Some preliminary results are now available. The best available extreme-value distribution for precipitation up to the 1970's was the Gumbel extreme-value distribution using a Weibull fitting formula. Recent statistical advances have brought new techniques to test data and frequency distributions, as well as provided better fitting techniques. The preliminary results from Pennsylvania and West Virginia using these techniques indicate that the Generalized Extreme Value (GEV) distribution better describes the frequency distribution for precipitation than does the Gumbel. The Gumbel is a special case of the GEV distribution. Fitting techniques have improved over the years with the Method of Moments being used in the 1970's and the Probability Weighted Moments (PWM) and L-Moment fitting techniques being more recent developments. These new fitting techniques are better able to utilize the shorter periods of record which are often a major problem in meteorology and hydrology. In addition, the techniques are also useful in the quality-control of data. Objective analysis schemes are also being explored to analyze isolines and to develop relations between the topography and precipitation frequency.

IV. WORK PLAN:

The review and revision of precipitation frequency information in the semi-arid southwestern states of Arizona, Nevada, New Mexico, Utah, southeastern California, and western Texas involves the following specific tasks. Some of the tasks need to be worked in sequence because of dependence on results from earlier tasks, some can be considered concurrently. The time table included at the end of the task descriptions (page 13) provides an indication of how the tasks will be managed. A brief discussion of the budget is presented in Section VIII, followed by a breakdown of costs according to the various tasks and other charges.

TASK 1
a) Data Collection b) Quality Control

A. Background

Some 20 years or more of data have accumulated since the completion of NOAA Atlas 2. In addition many stations that were not considered in that publication because of short records, now have as much as 30-40 years of useful records available. Furthermore, unknown quantities of supplemental data exist as a result of networks and stations maintained by Federal, State, county and private agencies, and not archived in NCDC. The attempt will be made to obtain the precipitation data from the northern portions of Sonora, Mexico.

B. Analyses

Both daily and hourly data will be used, and where available 15-minute data will be collected for use in short-duration relations, as well as other data of 1 hour or less collected by the NWS or within special networks. Because of interest in times of special flooding as well as a need for maximum values, the data will be sorted by month.

An attempt will be made to determine the quantity of relevant data available and bring it together in a consistent data base. To this end, use will be made of the knowledge and capabilities of State Climatologists to determine what information exists and how and from whom it may be obtained.

Database will be organized into three groups:

1) NWS precipitation gages (recording and non recording) used in NOAA Atlas 2 and those that could be employed in this analysis,

2) non-NWS precipitation gages and records not used in NOAA Atlas 2 that have data of sufficient length to test the old maps and to use in a new analysis, and

3) precipitation gages (both NWS and non-NWS) with records too short (less than 15 years after 1970) to evaluate return periods, but which could be employed in the analysis of events of interest, and eventually will have archived data for future analyses.

Seasonal distribution of precipitation for all durations will be examined. This requires careful attention to the definition of seasons in the semi-arid region of the Southwest. Quite likely the traditional definition of seasons (summer, winter, fall, spring) may not be applicable. In the Southwest it may be more appropriate to define a monsoonal season, rather than a summer or warm season. The seasonal definition may also be different for various sections within the region.

The seasonal definition probably varies as a function of the duration of the events being investigated. For example short-duration convective storms of 6 hours or less most likely occur most frequently from May through October. However, storms with a duration of 10 days or more most likely occur from October through April. Thus, there may be some overlap of months depending upon the duration of the storms being investigated. Delineation of season must be accomplished early during the data processing period to ensure that the data to be used in the frequency analysis is properly archived in the beginning. These decisions will be made in concert with the NWS, State Climatologists, state participants, and the Independent Advisory Group.

Of considerable importance is the need for quality control of the collected data. Procedures will be applied to the automated routine used in processing the data that will search for unusual extremes and note both missing and accumulated precipitation periods. The degree of quality control that exists in these data is unknown and quite likely varies considerably between various sources. Even the data archived by the NCDC need to be searched for punching or other errors.

The effort to process these data into a useable data base is of major importance to the overall reliability of the final product. It is understandable, therefore that this portion of the study will be given deliberate attention, as well as adequate time allotted, to accomplish this goal.

C. Product

A data base of all-available precipitation data for stations in the semi-arid southwestern states and the immediate surroundings will be created by this task.

TASK 2

Frequency Distribution/Fitting Studies

A. Background

The NWS has provided many studies of precipitation frequency over a period of some 35 years, and almost all these studies have been based on the Gumbel distribution (Fisher-Tippett Type I) fitted by the Gumbel fitting procedure (Weibull Plotting positions). Through the last 20-30 years, much research has described other statistical distributions and fitting techniques, each with an application to a particular type of data or location.

B. Analysis

It is important that in a major review, such as proposed herein, consideration be given to these recent developments, and an attempt made to incorporate any improvements that are real and can be supported. This task will select from the extensive literature those distributions and fitting procedures that appear most applicable. Some of these are the Generalized Extreme Value (GEV), the Pearson III, Generalized Log-Normal, the Gamma, the Generalized Pareto, Generalized Logistic distributions, and the L-moment, method of moments, and other fitting procedures, as examples. Tests and comparisons will be made to evaluate the application of each to the data from the region of study.

Results from a pilot study to update the precipitation-frequency data in the Pennsylvania-West Virginia area have provided much insight into recent statistical techniques and many of the problems that can be expected in a study of the precipitation-frequency relations for a region or a state. Some of the conclusions are: 1) problems in the reduction of data have been recognized and improved software will be developed for future work; and 2) the new statistical techniques provide improved ways of handling outliers in the data; 3) procedures for the quality control of precipitation data have been identified; 4) L-moment statistics, which is an evolution of probability-weighted moments, will be used for future frequency studies; 5) techniques for selecting the frequency distribution which best fits the data for an area have been developed and tested using L-moment statistics and other techniques.

This task will draw on the expertise of the Independent Advisory Group, State Climatologist, and state participants to guide the NWS toward the best solution in this area. Thought needs to be given to the benefits/drawbacks involved in solutions that result in regional variations between selected distributions and fitting procedures. This consideration may require sample tests be made in other regions outside the southwest. In the event different distributions are accepted, a discussion of boundary differences will be needed. Inter-regional consistency is important, but sometimes this can be mitigated by judicious choice of regional boundaries (e.g., consistent with major drainage limits).

C. Product

The outcome of this task will be the selection of a frequency distribution and fitting technique best suited to the precipitation data to be used in this study region.

TASK 3
Short-Duration Relations

A. Background

Short-duration information (durations of less than 1 hour) is valuable in the design for small-area structures, such as, drains, culverts, collections, and other similar hydraulic structures. Presently, NOAA Atlas 2 provides ratios adapted from a national average for durations of less than 1 hour. Other preliminary work by Frederick and Miller (1979) and Arkell and Richards (1986) shows that the ratio of rainfall less than 1 hour is different in the West from that in the East (Frederick et al. 1977), and that these ratios likely vary throughout the West.

B. Analysis

It is necessary to develop relations between 1 hour and shorter durations. Only limited digitized data are available for this analysis. These data sources include: 1) 15 minute and shorter periods available from Fischer-Porter gages as part of the national network maintained by the NWS; 2) special short-duration data from NWS first-order weather stations for intense storms; 3) break-point data from special dense raingage networks maintained by the Agricultural Research Service; and 4) short-duration data captured and archived by a variety of other Federal agencies, and local and state governments.

When analyzing these data we must be careful to maintain the spatial continuity of the meteorology of the data sets. For example, data from east of the Rockies will be useful for those regions east of the Rockies, but would probably

not be applicable to areas west of the Rockies. The major reasons for this are the difference in the moisture sources and the types of weather associated with the event. These homogeneous regions must be defined in the early part of the analysis. Special attention will also be paid to urban areas, if sufficient data exists, to determine if there are any differences in the intensity of rainfall in the downstorm direction.

Many of the storms will be due to convective activity. Another natural stratification of the data will be to determine if there are any differences in the temporal distribution of precipitation with height.

C. Product

The final products of these studies will be ratios or maps of ratios that can be applied to the 1-hour duration data to determine the frequency distribution of durations of less than 1 hour.

TASK 4

a) Algorithm/Data Plot (Algorithm Development/Application)

A. Background

For frequency calculations, not all portions of the semi-arid southwest are adequately represented by data. Therefore, it is important to develop algorithms or relations that are based on data-rich areas to be used in data-poor areas.

B. Analysis

Previous studies show that the geographical distribution of gaging stations varies significantly throughout the region. An objective technique is needed that will allow the analyst or the computer to provide a consistent rule throughout. Investigation of precipitation-terrain relations will be made in data-rich areas to develop algorithms for use in those regions where there are little or no data. A series of topographic and/or meteorological variables are often selected to apply in such studies. These could include distance from moisture sources, seasonality, slope, elevation, height above an arbitrary level, distance from a barrier, etc., as examples. Other data that will be investigated are satellite climatologies providing added definitions about the distribution of precipitation and thunderstorms in data-poor regions.

This task will be coordinated with both the State Climatologists for their knowledge of local variations and anomalies, and the Independent Advisory Group for their experience and recommendations.

C. Product

The most important product in this task is the set of precipitation-terrain relations that apply in data-sparse regions.

b) Frequency Calculations and c) Algorithm Calculations

A. Background

Once the data base has been established in task number 1, and the various relations determined as in tasks number 2 to 4, the data will be processed to obtain various outputs.

B. Analysis

Precipitation frequency values for durations between 5 minutes and 10 days at return periods between 2 and 100 years will be calculated for all stations within and surrounding the semi-arid region. Results will be obtained both monthly and on a maximum annual basis. Consideration will be given in the digital process to establish routines that will allow bi-monthly or weekly products, if needed, to be computed. However these decisions must be made in the beginning, so data-processing costs do not become too expensive.

The results will be examined for inconsistencies, errors, or meteorological unreasonableness. An important part of the study is to provide information that makes sense and can be supported by meteorological experience and theory. Local judgment will be included before these results are confirmed. This is a final form of quality control.

C. Product

The product from this task will be a consistent set of precipitation frequency values and relations.

d) Final Adjustments (Frequency Relation)

A. Background

After all the frequency values are calculated, the spatial analysis of these values will begin. Algorithms will be used to develop relations between the precipitation frequency data and the underlying terrain. Further smoothing will be provided by regionalization of the frequency relations. This ensures that the frequency relations within a region are homogeneous and account for any unusual singular points in the data set and the underlying terrain.

B. Analysis

For selected durations and return periods (e.g., 2-yr 1-hr, 2-yr 24-hr, 2-yr 10-day and comparable 100-yr values), the calculated frequency values will be plotted and an objective spatial analysis program will be used to analyze the results. These analyses will be reviewed for internal consistency, known local effects, meteorological reasonableness, and to develop any supplemental hard copy analyses. The objective spatial analysis program will regionalize the data, providing a smoother final analysis that will account for the underlying terrain.

Seasonal relations can be developed for selected frequency/return periods either by month or by mid-season month, or seasonal average. Tests will be made to provide comparative information that will allow the best relation to be chosen. Comparisons will also be made to other indices, such as runoff.

C. Product

The product from these studies will be a set of frequency maps at least for the annual maximum precipitation for durations probably from 1 hour to 10 days, for various return frequencies up to 100 years. These frequency maps will provide the detail of the effects of terrain. Relations will be given to relate the 1-hour data to smaller durations for general storms, and either a set of maps or relations in table form will be given to relate the annual maximum values to seasons. As part of this task, the method of presentation will be examined to determine if alternate methods of presentation of the frequency relations are possible. Final decisions will be made after consulting with the Independent Advisory Group, the State Climatologists, and the states involved with the project.

TASK 5

Spatial/Temporal Relations (Depth-Duration and Depth-Area Studies)

A. Background

These studies will be divided into two parts. The first part will examine depth-durations or mass curves for durations of 1 hour or less and depth-area curves for area sizes of 100 miles^2 or less. Such relations provide information for use over small areas and for short durations, and concentrate on local thunderstorms. The focus of the second part of the study will be on depth-duration curves from 1 hour through 10 days, and the depth-area results will explore areas of 500 miles^2 or greater. These results will give details about the longer duration and more generalized storms. This data base will develop information from convective storms, tropical storms and general storms.

B. Analysis

The depth-duration studies for small-area storms will concentrate on convective storms to identify the maximum intensity of rainfall in periods of 1 hour or less. A family of meteorologically consistent mass curves will be prepared. The data base will contain rainfall for periods of less than 1 hour. Arkell and Richards (1986) and Frederick and Miller (1979) have shown that there are different subregions within the area. As a result, special attention must be paid to define the homogenous subregions. If sufficient data exists, urban areas will be examined to determine if there are any differences in the intensity of rainfall downstorm of the city. Another natural stratification of the data will be to determine if there are any differences in the temporal distribution of precipitation with elevation.

Depth-area relation for areas up to 100 miles^2 are also important in the design of small area hydraulic structures. The data from the dense raingage networks will be utilized to develop depth-area curves for durations from 5-or-15 minutes, if possible, to 24 hours for areas up to 100 miles^2.

In addition to short-duration, small-area relations, it is important that depth-duration and depth-area curves be established for duration from 1 hour to 10 days, and for areas greater than 500 miles^2. The data base for this analysis will be derived from the extreme events identified in the data processing procedure. This will include data from the NWS national network, and data from the various dense raingage networks and the individual stations of various Federal, state, local, and private groups.

The depth-duration or temporal analysis of the data will follow the scheme developed by Huff (1967) and Huff and Vogel (1976) which identifies families of mass curves. These families of curves provides a range of meteorologically possible non-dimensional mass curves, showing the median and the extreme possible mass curves that can occur. Durations for this analysis will range from 1 hour up to 10 days. Consequently, a series of non-dimensional mass curves will be assembled that will encompass this wide variation of durations. The analysis will provide extreme point estimates and consider areal-averaged mass curves. For this semi-arid area of the United States there will be differences between convective storms and general storms, the data will be stratified to identify these differences. It will also be necessary to identify any regional variations and differences with elevation.

C. Products

The final products of these small-area, short-duration studies will be relations that can be plotted and smoothed for use in small-area design problems.

Area-depth curves will also be derived for areas greater than 500 miles^2. If possible, a family of curves will be developed to show the extreme area-depths that are possible. These curves will be stratified by duration and area size to maximize the utility for design purposes. A smoothed set of curves will also be generated for generalized results. Regional and elevation variations will be identified, and curves will be generated to distinguish between general storms, tropical storms and convective storms where such stratifications are possible and meteorologically reasonable.

Families of mass curves and area-depth curves will be generated and displayed as a function of the duration and area size. If the data permits, the analysis will also be displayed by storm type and elevation.

TASK 6

Deliverables (a) Atlas (b) PC Package (c) Final Report.

This study will produce a final report that will be published in one of the NOAA series with initial distribution according to a mailing list developed by the NWS and the participants. Further distribution will be made through NTIS, and from a reserve supply maintained by the NWS.

The report will contain detailed discussion of the data and procedures used to obtain precipitation frequency values along with background and information about studies made to arrive at these conclusions. Maps of analyzed results

will be provided along with graphical relations needed to obtain intermediate values. Seasonal variation, depth-area distribution, and the temporal distribution of rainfall in extreme storms will be discussed, and graphs and figures appropriate to defining these results for the region will be given.

In addition, and unique to this study, a digital file will be created so that the results at any location in the region and the data bases can be obtained. It is intended that the digital file will be a practical solution to most field users needs, particularly those who make continual reference to these data, or wish to incorporate these results into some larger computational routine.

Note: The digital file will be in the GIS form.